09/582120
430 Rec'd PCT/PTO 22 JUN 2000

METHOD AND DETERMINATION DEVICE FOR THE IMPLEMENTATION OF THE METHOD FOR DETERMINING A CONNECTING PATH IN A COMMUNICATION NETWORK

The present invention is directed to a method for determining a connecting path in a communication network as well as to a corresponding switching equipment for use in communication networks, particularly in communication networks having hierarchically complete determination of connecting paths.

As known, communication networks are composed of a plurality or network or switching nodes that are connected to one another according to a specific network topology. Subscriber terminal equipment can be connected to some of these network nodes as user-specific line units of a communication network, whereas other network nodes serve only as transfer nodes, i.e. for forwarding communication information.

By way of example, Figure 3a shows the structure of a binary-like [sic] communication network structure. According to Figure 3a, the communication network shown by way of example comprises a total of ten network nodes K_1 - K_{10}. A plurality of subscriber terminal equipment EG_{11} - EG_{43} are respectively connected to the network nodes K_1 - K_4. These network nodes K_1 - K_4 form the lowest hierarchy level of the communication network shown in Figure 3a and are referred to as local network nodes. The local network nodes K_1 - K_4 are connected to one another with corresponding connecting paths via the other network nodes K_5 - K_{10}. According to the example shown in Figure 3a, no subscriber terminal equipment are connected to the network nodes K_5 - K_{10}, so that these network nodes serve only as transfer or switching nodes. The network nodes K_5 - K_7 correspond to regional network nodes and serve the purpose of connecting the local network nodes K_1 and K_2, K_2 and K_3 or, respectively, K_3 and K_4. Correspondingly, the network nodes K_8 and K_9 serve for connecting the regional network nodes K_5 and K_6 or, respectively, K_6 and K_7 and are referred to as super-regional network nodes. Finally, the node central K_{10} that

connects the super-regional network nodes K_8 and K_9 to one another forms the highest hierarchy level of the communication system shown in Figure 3a. When, for example, the subscriber EG_{42} is called from the subscriber terminal equipment EG_{12}, a connecting path or, respectively, connecting route must be set up via the communication network proceeding from the local network node K_1 to the local destination network node K_4 of the called subscriber. There are thereby a number of connecting possibilities according to the communication network shown in Figure 3a. One connection, for example, could lead via the network nodes K_1 - K_5 - K_8 - K_{10} - K_9 - K_7 - K_4. Another connecting possibility would be the connecting path via the [...] K_1 - K_5 - K_2 - K_6 - K_3 - K_7 - K_4, etc. The individual network nodes K_1 - K_{10} are formed by switching equipment whose jobs include determining the suitable connecting path from a calling terminal equipment to a called terminal equipment and setting up the corresponding connection.

Whereas Figure 3a shows a tree-like communication network structure, Figure 3b shows a cube-like communication network structure, whereby, in particular, respectively three network nodes K_1 - K_3 form a network node group that is connected via corresponding connecting lines to a neighboring network node group that is likewise composed of three network nodes. Terminal equipment can be optionally connected to each of the network nodes shown in Figure 3b or the corresponding network node can merely serve as transfer node without terminal equipment connected thereto.

Due to the currently increasing need for digital communication networks with great bandwidths and high transmission rates, what is referred to as the ATM transmission principle (asynchronous transfer mode) has prevailed for data transmission in communication networks. According to this ATM transmission principle, the data to be transmitted are communicated in the form of what are referred to as ATM cells that are composed of a header and an information field. The header contains address or, respectively, control information of the corresponding ATM cell, whereas the information field comprises the actual payload information. The address

information contained in the header are employed for the routing of the payload information within the communication network. The data transmission from one network node to another ensues optically, i.e. via light waveguides.

In communication networks having hierarchically complete path determination, the network topology of the communication network is stored and, thus, known in the individual network nodes. Each network node or, respectively, the corresponding switching equipment of this network node is thus informed, for example, about how many and which other network nodes are present in the communication network, which connecting lines or, respectively, connecting paths exist between the individual network nodes and what transmission properties (for example, transmission capacities and transmission statusses) the corresponding connecting paths have. On principle, thus, every network node is in the position to determine a hierarchically complete connecting path to a desired destination node of the communication network. As a rule, the complete connecting path is defined by that network node to which the calling terminal equipment is connected (see the network nodes K_1 - K_4 in Figure 3a). After receiving the corresponding connection request (for example, to the terminal equipment EG_{42} shown in Figure 3a), the originating node determines the entire path through the communication network up to the desired destination node on the basis of the information about the communication network available to it. After defining the suitable connecting path, the originating node or, respectively, the switching equipment thereof generates an information element in which the individual network nodes to be traversed along the defined connecting path are defined. Additionally, the connecting lines (ports) can also already be defined in the information element. Together with a pointer, this information element is communicated to the individual network nodes participating in the defined connecting path, whereby the pointer respectively points to the next network node to be approached. When, for example, a connection is requested from the terminal equipment EG_{12} shown in Figure 3a to the terminal equipment EG_{42} and when the originating node K_1 has selected the route K_1 - K_5 - K_2 - K_6 - K_3 - K_7 - K_7

[sic] - K_4 for this connection, the individual network nodes K_5, K_2, K_6, K_3, K_7 and K_4 to be approached are successively deposited in the corresponding information element in the form of a stack memory, whereby the pointer of the information element points first to the network node K_5.

In order to keep the connection setup times relatively short, the connecting paths to every potential destination node of the communication network are determined in advance and stored in the individual network nodes. Due to the different quality demands (for example, bandwidth, delay, etc.) of a connection request or, respectively, of a connection inquiry and due to the increasing complexity of the communication networks, all possible connecting paths from an originating node to a destination node can usually not be calculated in advance and stored. First, there is thereby the risk of inadequate memory space; second, not all possible alternative paths are in fact usually made use of. Further, the time required for a connection setup lengthens if all possible alternative paths must be searched before the actual connection setup before the ultimately suited connecting path was capable of being found. When, on the other hand, all of the pre-calculated connecting paths fail to satisfy the demands of a connection request (for example, with respect to the bandwidth or transmission rate), a suitable connecting path must first be newly determined on the basis of the available network information. This can be a very time-intensive procedure dependent on the complexity of the communication network, as a result whereof the connection setup can be substantially delayed or, respectively, even jeopardized. As a compromise, only a specific plurality of standard connecting paths are therefore stored in each network node. To this end, standard values are assumed for the individual connecting paths to each network node of the communication network with respect to the quality demands of the corresponding connection request, and, for example, only the respectively shortest path or paths to each potential destination node is/are calculated and stored. Given a pending connection request, all pre-calculated and stored connecting paths are then checked to see whether they meet the quality demands of the pending connection request. When

one of the pre-calculated connecting paths meets the quality demands, this is employed for the connection setup to the requested destination node. When, however, none of the pre-calculated connecting paths meets the corresponding quality demands, a suitable alternative path to the requested destination node is determined on the basis of the stored network topology data and employed for the connection setup.

However, the above-described procedure has the disadvantage that, dependent on the pending connection request, it is still not possible to preclude relatively long connection setup times since only a relatively slight number of standard connecting paths is pre-calculated and stored, so that a suitable alternative path must potentially be determined first when none of these pre-calculated standard connecting paths can meet the quality demands of a requested connection, which can in part be very time-intensive dependent on the complexity of the communication network.

Further, United States Letters Patent US-A-4,862,496 discloses a method for traffic routing in a line-switching communication network, particularly upon setup of a connection between neighboring switching nodes, that selects a second path on the basis of further connecting paths predetermined in the respective switching nodes, whereby, given the occurrence of an overload on the preferred connecting path, the connection to be switched is discarded and one of the predetermined, further connecting paths is selected as current alternate connecting path. When, for example, the direct path between a first network node and a neighboring, second network node that is provided for the connection setup is overloaded, then the connection can be set up via the current alternate connecting path prescribed in the first network node. Such traffic routing methods for line-switching communication networks are assigned to the species of "hop-by-hop routing" methods in the technical field.

The present invention is therefore based on the object of creating an improved method for determining a connecting path in a communication network as well as a ch switching equipment for a communication network, whereby the time required for setting up a requested connection can be shortened.

According to the present invention, this object is achieved by a method comprising the features of claim 1 as well as a switching equipment comprising the features of claim 11. The subclaims describe advantageous developments of the present invention that in turn contribute to a further shortening of the connection setup times or, respectively, to assuring the determination of a suitable connecting path.

According to the present invention, a dynamic connecting path memory is established. When a connection request or, respectively, a connection inquiry pends, this connecting path memory is searched for a suitable connecting path to the requested destination node. When the stored connecting paths do not meet the demands of the connection request, a suitable alternative path to the requested destination node is determined on the basis of the stored network topology data and entered into the dynamic connecting path memory, whereby the connecting paths deposited in the dynamic connecting path memory remain stored in the corresponding switching equipment beyond the duration of the connection.

This dynamic connecting path memory can be alternatively or additionally present to the initially described memory with pre-calculated, standard connecting paths. When the dynamic connecting path memory is present in addition to the memory with pre-calculated, standard connecting paths, the memory with pre-calculated, standard connecting paths is searched first upon arrival of a connection inquiry for a suitable connecting path to the requested destination node that also meets the demands of the connection request. When all pre-calculated, standard connecting paths are unsuitable for the pending connection request, the connecting paths stored in the dynamic connecting path memory are searched in the next step. When, at this time, there is still no entry in the dynamic connecting path memory or, respectively, a suitable connecting path that meets the demands of the connection request is also not deposited in the dynamic connecting path memory, a suitable alternative path is determined on the basis of the stored network topologies and is entered into the dynamic connecting path memory. This connecting path is subsequently employed for the connection setup.

The dynamic connecting path memory can comprise a predetermined, maximum plurality of destination node-specific memory locations. When a new connecting path is to be entered in the dynamic connecting path memory and when all n memory locations are already occupied, the connecting path situated longest in the dynamic connecting path memory can, for example, be overwritten. It is likewise possible to overwrite the connecting path that is employed least often. When a connecting path stored in the dynamic connecting path memory is eliminated or, respectively, when this becomes invalid, for example because sub-paths or network nodes that are employed are down, the corresponding connecting path is removed from the dynamic path memory, i.e. erased.

The maximum plurality n of memory locations of the dynamic connecting path memory can be permanently prescribed or can be adjustable. It is advantageous to acquire the plurality of "overflows" per defined time unit of the dynamic connecting path memory and to increase the maximum plurality of memory locations of the dynamic connecting path memory dependent thereon. After expiration of a specific time span, the maximum plurality of available memory locations can in turn be reset after an incrementation, using a timer control.

A self-optimizing connecting path table is established in the corresponding network node, i.e. the corresponding switching equipment, of the communication network as a result of the inventively proposed employment of a dynamic path memory. It is assured in this way that the memory resources are protected against connecting paths that are only rarely or never employed. Further, it is only necessary to calculate a few or, respectively, absolutely no pre-calculated, standard connecting paths. The connection setup times are shortened on average due to the employment of the dynamic connecting path memory since, as a result of the dynamic connecting path memory, the probability increases substantially that a connecting path that is already suitable is available for an incoming connection request.

The present invention can be applied both to broadband networks as well as to narrowband networks and is independent of the communication standard respectively employed for the data transmission.

The invention is described in greater detail below on the basis of preferred exemplary embodiments with reference to the attached drawing. Shown are:

Figure 1 a schematic block circuit diagram of the structure of a first exemplary embodiment of the inventive switching equipment;

Figure 2 a schematic block circuit diagram of the structure of a second exemplary embodiment of the inventive switching equipment; and

Figures 3a and 3b exemplary communication network structures.

Figure 1 shows a switching equipment 1 that is a component part of every network node of a communication network that, for example, can be structured as in Figures 3a or 3b. The switching equipment 1 comprises a plurality of line units 2 that are respectively connected to a subscriber terminal equipment or to another switching equipment of another network node. The line units 2 convert the incoming information into digital data words to be internally processed. Further, the switching equipment 1 comprises a switching device or means 3 that serves the purpose of producing a physical connection between the individual line units 2 of the switching equipment for the transmission of data between the paths connected to the corresponding line units 2. The switching means 3 comprises a plurality of individual switching elements that form a switching network. The switching means 3 is the actual switching location of the switching equipment 1. Further, the switching equipment 1 comprises a control unit 4 fashioned, for example, in the form of a microprocessor that forms the heart of the switching equipment 1 and serves for the drive and monitoring of the individual line units 2 as well as of the coupling means 3. Among other things, the control unit 4 sees to the synchronization of the individual line units 2 to the internal clock of the switching equipment 1 and for defining the physical connections between the individual line units 2 that are to be realized by the switching means 3. The control unit 4 thus determines via which path or,

respectively, via which line unit 2 the communication data received via a different line unit 2 are to be forwarded or, respectively, output.

Further, the switching equipment 1 shown in Figure 1 comprises a first memory 7 in which the data of the network topology of the corresponding communication network are comprehensively stored. Particularly stored in this first memory 7 are how many and which other network nodes the communication network comprises, which connecting lines or, respectively, connecting paths exist between the individual network nodes and what transmission properties (such as, for example, transmission capacities or transmission statusses) these transmission paths comprise, etc.

The pre-calculated, standard connecting paths to the individual, potential destination nodes of the communication network that have already been explained above are stored in a second memory 6. As has already been explained, it is known from the Prior Art to pre-calculate specific, standard connecting paths to the individual, potential destination nodes of the communication network, whereby these standard connecting paths can, for example, respectively represent the shortest connecting path from the switching equipment 1 to another potential destination node of the communication network. Specific, standard connecting paths as well as the corresponding connection parameters or, respectively, connection properties (such as, for example, transmission capacity or transmission status) are thus stored in the second memory 6 in destination node-specific fashion. However, it is not absolutely necessary to store the connection parameters for every connecting path in the second memory 6 since, in principle, these information are already deposited in the first memory 7. In order, however, to keep the connection setup times as short as possible, it is advantageous to deposit the corresponding connection parameters or, respectively, connection properties at the same time for each connecting path deposited in the second memory 6. It is assumed in the exemplary embodiment shown in Figure 1, that, in addition to comprising the switching equipment 1, the corresponding communication network comprises a further N, other switching

equipment that serve as potential destination nodes for a communication connection with the switching equipment 1. One or more standard connecting paths can be stored for each potential destination node.

The switching equipment 1 also comprises a third memory 5 that serves as dynamic connecting path memory. The memory 5 is initially empty at the initial commissioning of the switching equipment 1.

The function of the switching equipment shown in Figure 1 or, respectively, the control unit 4 thereof is as follows.

When a connection inquiry or, respectively, a connection request is received via one of the line units 2, the control unit 4 must first determine a suitable connecting path to the requested destination node before the setup of the corresponding connection, whereby, in particular, the connecting path must do justice to quality demands made of the requested connection (for example, bandwidth, transmission rate, etc.) that are potentially prescribed in user-specific fashion. To this end, the control unit 4 initially searches the standard connecting paths to the desired destination node that are stored in the second memory 6. On the basis of the connection properties of the corresponding, standard connecting paths to the requested destination node that are likewise deposited in the second memory 6, the control unit 4 can determine whether the second memory 6 comprise [sic] a connecting path to the requested destination node that is suited for the requested connection properties. When this is the case, the corresponding connecting path is read out from the second memory 6 and employed for the connection setup. When, however, the control unit 4 has not found a suitable connecting path to the requested destination node in the second memory 6, the control unit 4 (with reference to the network topology data stored in the first, network topology memory 7) determines a suitable connecting path to the requested destination node that, in particular, meets the quality demands of the connection request.

Subsequently, this alternative path determined by the control unit 4 is entered in the third, dynamic connecting path memory 5. The entry ensues

destination node-specifically and can, as shown in Figure 1, also comprise the connection parameters or, respectively, transmission properties of the corresponding, identified connecting path. The entries in the third, dynamic memory 5 thereby ensue in the sequence of the determination of the corresponding connecting paths by the control unit 4. Advantageously, the determined connecting paths are therefore stored in the third memory 5 in the form of an FIFO stack. As can be derived from Figure 1, the third, dynamic memory 5 is not limited to one entry per potential destination node; rather, a plurality of connecting paths (potentially with different transmission properties) can be entered for each destination node. After entry of a connecting path in the third memory 5, the corresponding connecting path determined by the control unit 4 is employed for the connection setup to the requested destination node. The entries in the third memory 5 also remain stored in the third memory 5 beyond the connection duration of the respectively corresponding connecting path.

When further connection requests are subsequently received at the switching equipment 1, the control unit 4 searches not only the pre-calculated, standard connecting paths to the requested destination node that are stored in the second memory 6 but also searches the entries deposited in the third, dynamic memory 5. Only when suitable connecting paths to the requested destination node are found neither in the second memory 6 nor in the third, dynamic memory 5 does the control unit 4 again determine a suitable connecting path on the basis of the network topology data stored in the second memory 6 and subsequently enter this in the third memory 5.

The scope of the third memory 5 can be either permanently prescribed or variable. Before entry of a newly determined connecting path into the third memory 5, the control unit 4 regularly monitors the memory occupation of the third memory 5. When a newly determined connecting path is to be entered into the third memory 5 even though a maximum plurality n of memory locations is already occupied, the control unit according to the first exemplary embodiment shown in Figure 1 overwrites the connecting path that has been stored longest in the third memory 5.

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When a connecting path has become invalid in the interim, for example because sub-paths or network nodes that are used have failed, this connecting path is potentially removed both from the memory 6 as well as from the third memory 5.

The connection setup times can be shortened on average by employing the third, dynamic memory 5, since the probability increases substantially that a suitable connecting path is available either in the second memory 6 or in the third memory 5. In particular, the third memory 5 contains only entries of connecting paths that have already met certain quality demands of a corresponding connection request. The entries of the third memory 5 are thus higher in quality compared to the entries of the second memory 6 and therefore contribute to the shortening of the connection setup times since they clearly enhance the probability of finding a suitable connecting path.

After the control unit 4 of the switching equipment 1 -- as described above -- has determined a suitable connecting path to the requested destination node, the control unit 4 generates the aforementioned information element in which the individual network nodes of the communication network that are to be traversed according to the determined connecting path are deposited. This information element is communicated from the control unit 4 via a corresponding line unit 2 to the first network node of this connecting path and comprises a pointer that always points to the next network node to be approached in the communication network. The network node of the communication network that is approached first thus forwards the pointer to a network node after reception of this information element.

Of course, the switching equipment 1 shown in Figure 1 can also be employed without the second memory 6 with the pre-calculated and stored, standard connecting paths to the individual, potential destination nodes of the communication network. In this case, the control unit 4 searches only the entries of the third memory 5 upon arrival of a connection inquiry and determines a suitable connecting path on the basis of the network topology data stored in the first memory 7 if the third memory 5 has no suitable connecting path entries. Subsequently, the newly

determined connecting path is deposited in the third memory 5 and is then available for the determination of a new connecting path.

It has already been explained with reference to the second memory 6 that the storing of the connection parameters of the corresponding connecting path in the second memory 6 is optional. This also applies to the entries in the third memory 5. With respect to the third memory 5, too, it is fundamentally adequate when only the determined connecting path to the corresponding destination node is stored, since the transmission properties or, respectively, connection parameters corresponding to the connecting path are stored in the first memory 7. The storing of the connection parameters together with the corresponding connecting path in the third memory 5, however, is advantageous since the control unit 4 need not additionally access the entries in the first memory 7 subsequently in the determination of a new connecting path in order to identify the corresponding transmission properties of the respective connecting path.

Figure 2 shows a second exemplary embodiment of the inventive switching equipment.

The switching equipment 1 shown in Figure 2 as well as the function thereof essentially corresponds to the switching equipment shown in Figure 1. According to the second exemplary embodiment, however, the switching equipment 1 also comprises an overflow counter 8. This overflow counter 8 acquires the plurality of overflows of the third, dynamic connecting path memory 5. I.e., the counter reading of the overflow counter 8 is always incremented by 1 when the control unit 4 wishes to enter a new connecting path in the third memory 5 even though a number of connecting paths corresponding to the predetermined maximum plurality n is already stored. The control unit can determine the number of "overflows" of the third memory 5 during a defined time span on the basis of the counter reading of the overflow counter 8 and can correspondingly adapt the memory scope of the third memory 5 dependent thereon, i.e. raise or lower the maximum plurality n of the entries of the third memory 5. When the maximum plurality n of entries of the third

memory 5 was raised or lowered, the control unit 4 in a version of the second exemplary embodiment shown in Figure 2 can in turn reset the maximum memory scope n of the third memory 5 to the original value after the expiration of a corresponding time span.

Another characteristic of the exemplary embodiment shown in Figure 2 is the fact that, in addition to the data shown in Figure 1, the control unit 4 also stores the frequency of use of each connecting path deposited in the third memory 5. This means that, given employment of a connecting path stored in the third memory 5, the control unit likewise increments the counter of this connecting path stored in the third memory 5 by 1. This version makes it possible for the control unit 4 to overwrite the least frequently employed connecting path of the third memory 5 with a newly determined connecting path when the maximum plurality n of memory locations of the third memory 5 is already occupied.

Particularly as a result of monitoring the frequency of use of each connecting path deposited in the third memory 5, the third memory 5 forms a self-optimizing connecting path table. The quality of the entries of the third memory 5 increases with the operating duration of the switching equipment 1 or, respectively, with the plurality of connections requests arriving at the switching equipment. This self-optimizing connecting path table assures that connecting paths that are only used seldom or not at all do not remain stored in the third, dynamic memory 5 over a longer time.

By employing the third, dynamic memory 5, i.e. a memory whose content dynamically changes with the operating duration of the switching equipment, only a few or, respectively, potentially absolutely no standard connecting paths need be calculated in advance and stored (in the second memory 6).